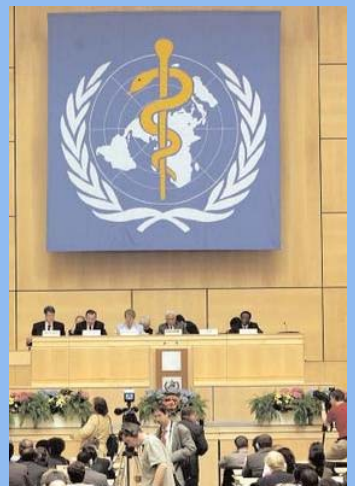
World Health Organization

Georgia Institute of Technology

Resource Allocation for Malaria Prevention

Final Presentation

April 17, 2008



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Agenda

- Client Background
- Problem Description
- Solution Strategy
- Model
- Deliverables
- Value

Client Background

- World Health Organization
  - Responsible for providing leadership to all UN member nations on global health matters

- Public Health Mapping Group
  - Data analysis, process and visualization via Geographic Information Systems (GIS)

Problem Description

- Malaria
  - 300-500 million cases per year and over 1 million deaths
  - Prevention methods
    - Indoor Residual Spraying (IRS)
    - Long-Lasting Insecticide Treated Bed Nets (LLIN)

- No existing procedure for optimal allocation of limited prevention resources
  - Arbitrary distribution
  - Detrimental effects of excessive spraying

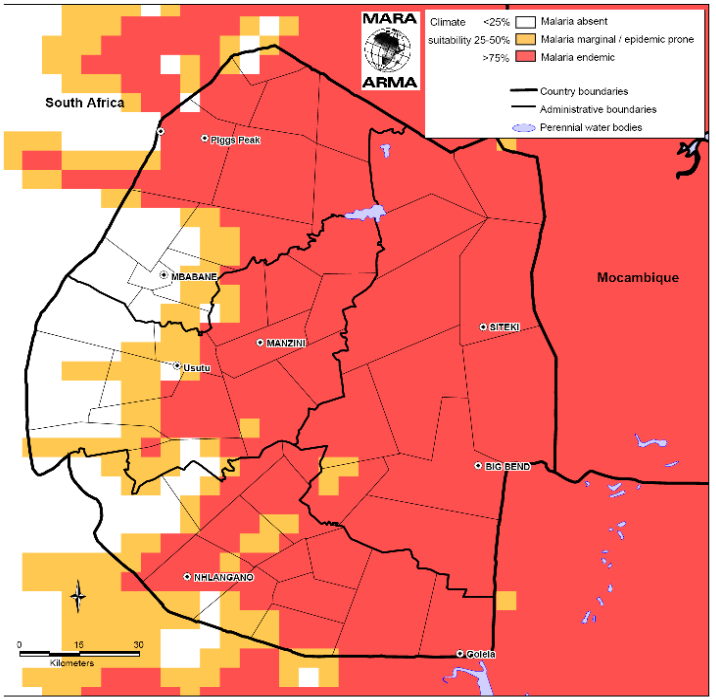
Solution: Strategy

- Create a systems-based approach to minimize the incidence of malaria with limited resources.

- Swaziland as pilot country
  - Historical data availability
  - Wide range of conditions

http://en.wikipedia.org/wiki/Swaziland

Swaziland: Distribution of Endemic Malaria

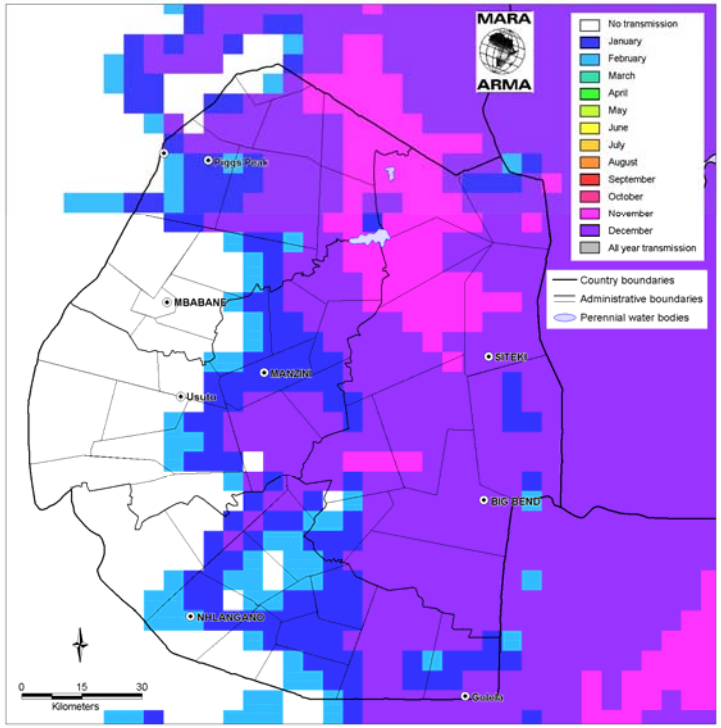


http://www.mara.org.za/

Data Sources

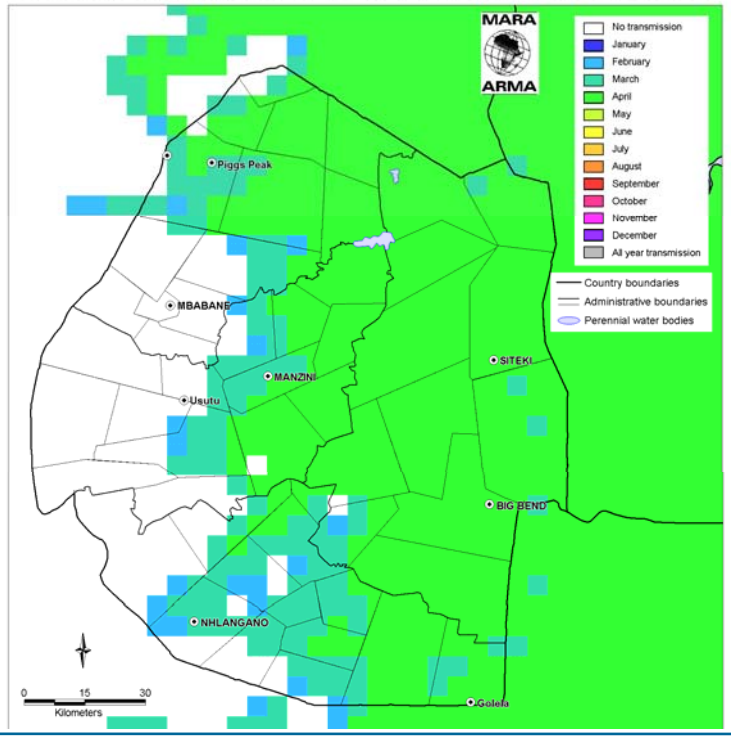
- Mapping Malaria Risk in Africa (MARA)
  - Percentage risk estimation by region
  - 5x5 km spatial resolution
  - Start and end months of high malaria transmission

Swaziland: First Month of the Malaria Transmission Season



http://www.mara.org.za/

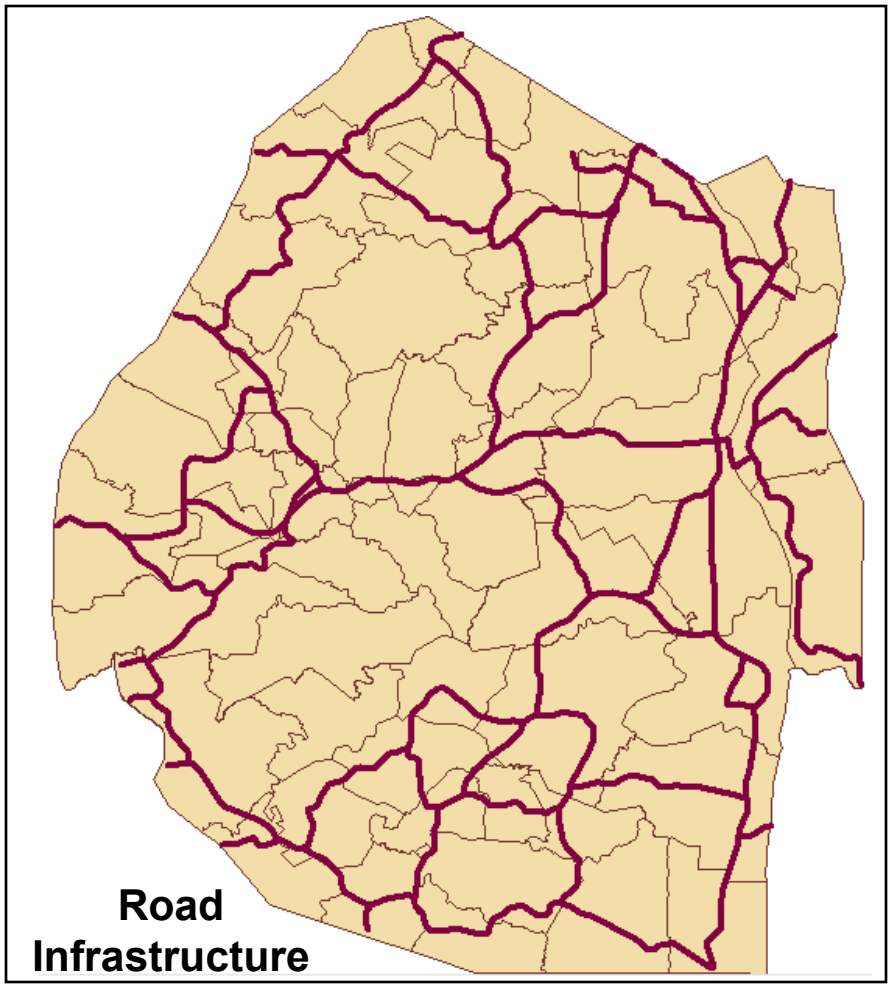
Swaziland: Last Month of the Malaria Transmission Season

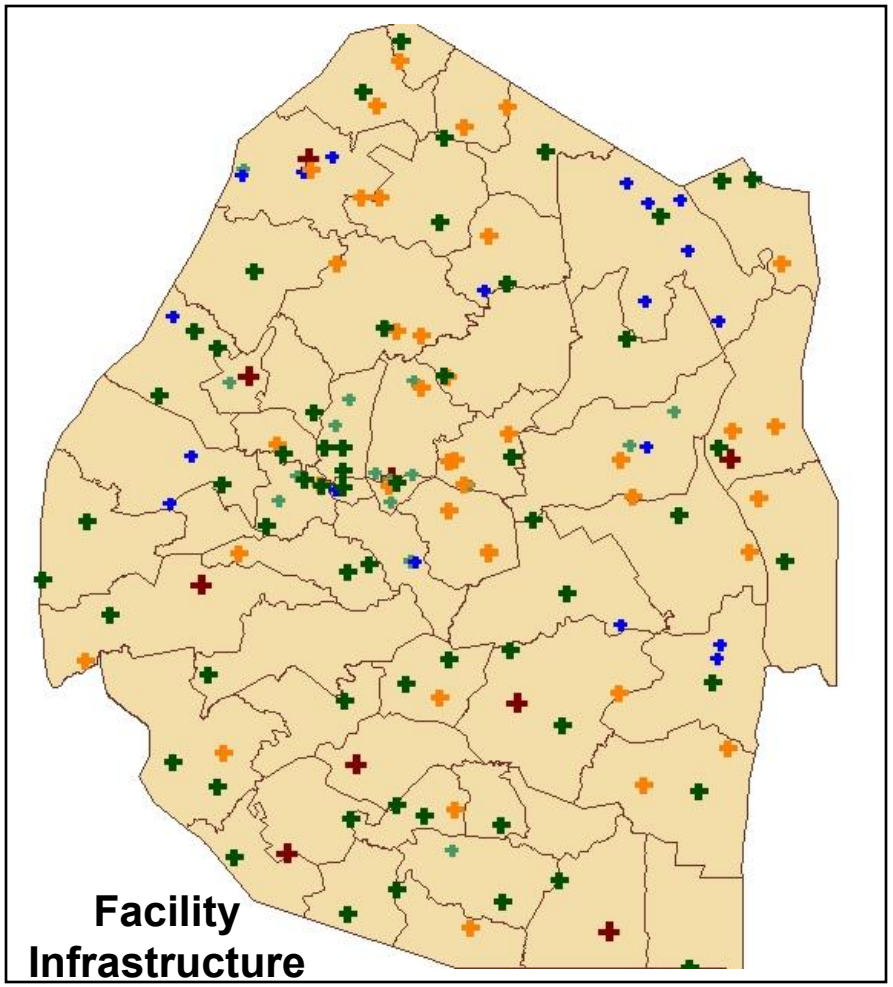


http://www.mara.org.za/

Data Sources

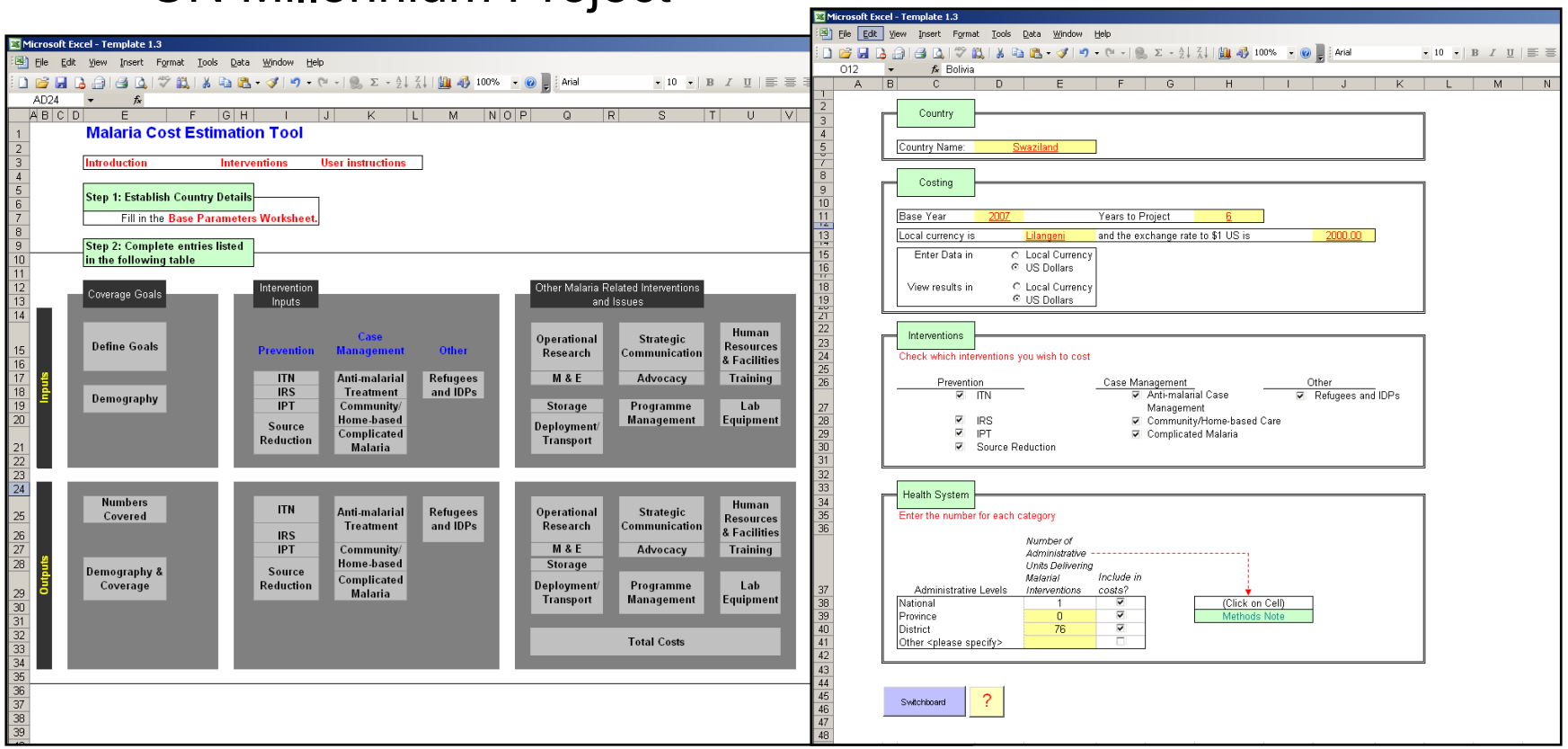
→ HealthMapper





Data Sources

- Costs and other intervention data
  - World Health Organization Malaria Costing Tool
  - UN Millennium Project

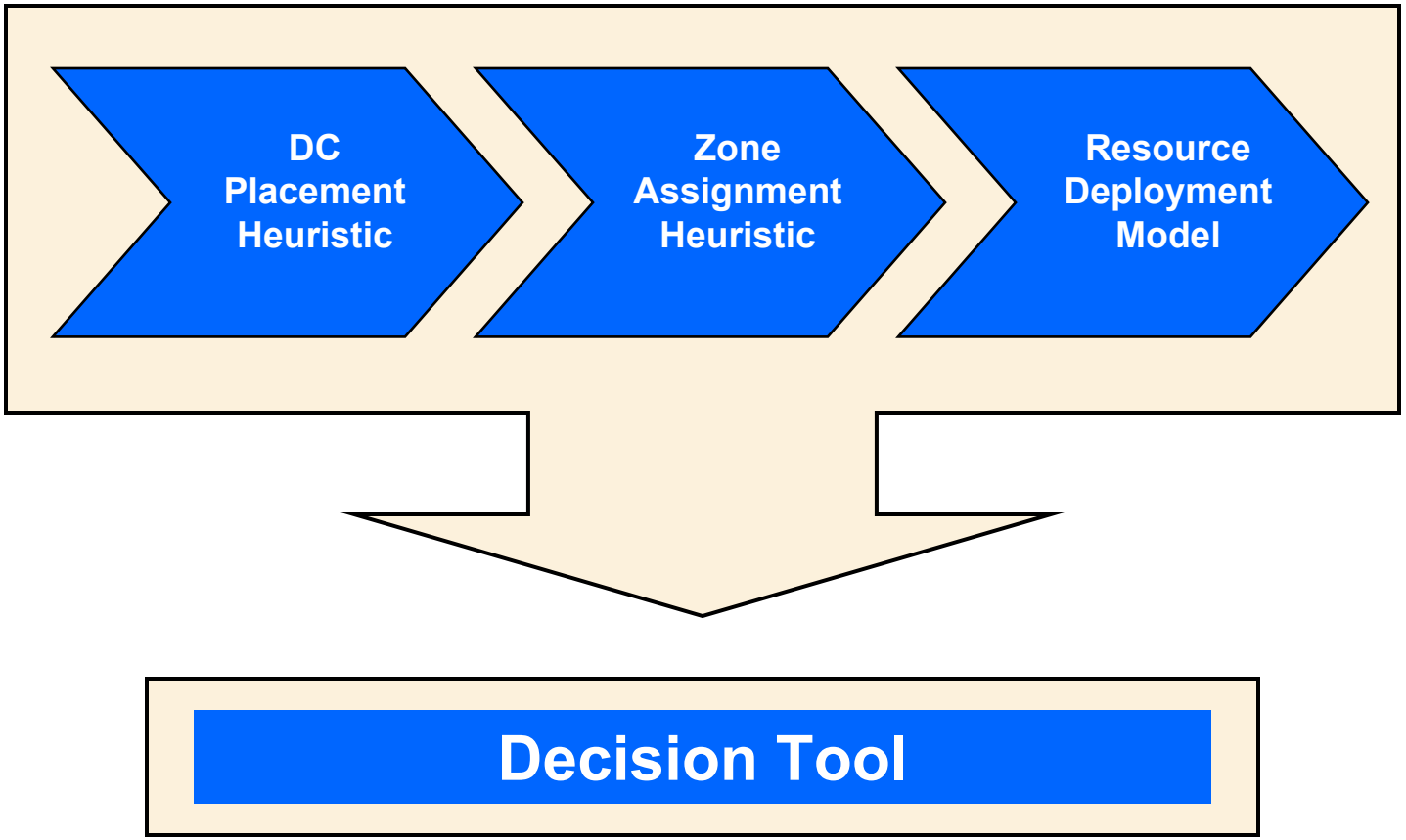


Model Objective

- An optimization model will allow for a systems-based approach to resource allocation and deployment for malaria prevention.

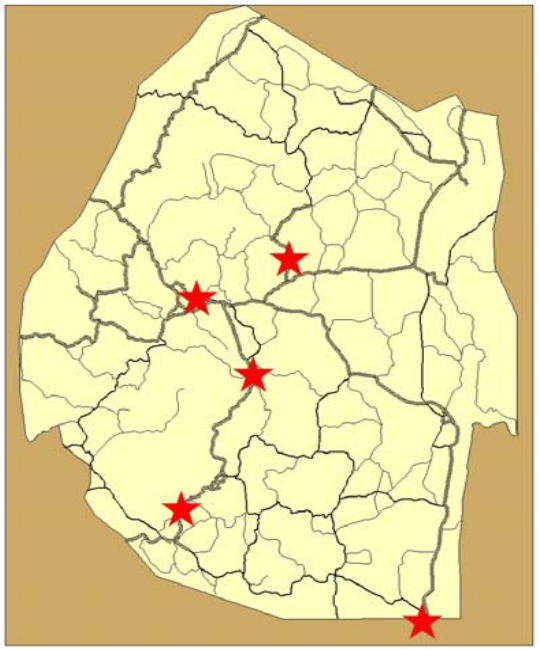
- Decisions include:
  - Where to locate Distribution Centers (DCs)
  - How many DCs to open
  - When DCs should be open
  - What regions DCs should serve
  - When to cover each zone
  - Number of people to protect in each zone
  - Labor, trucks, equipment, insecticide/nets to base at DCs
  - Labor, trucks, equipment to allocate to each zone

Model Overview



DC Placement Heuristic

- Potential locations for DCs
  - Factors considered:
    - Population
    - Malaria risk
    - Infrastructure



- Scalable for other countries
  - Distance constraints adjusted by estimated area

Max. distance from center point: $\frac{d \cdot \sqrt{2}}{2}$

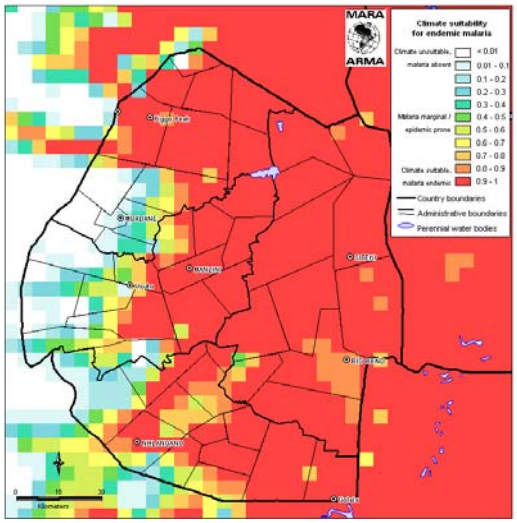
Min. distance between DCs: $\frac{d \cdot \sqrt{2}}{n / 2}$

*where *d* represents ½ the (estimated) height of the country, and *n* the number of DCs

DC Placement Heuristic

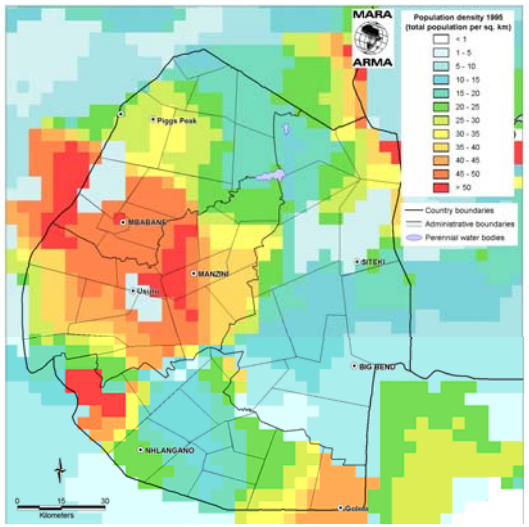
Malaria Risk

Swaziland: Distribution of Endemic Malaria

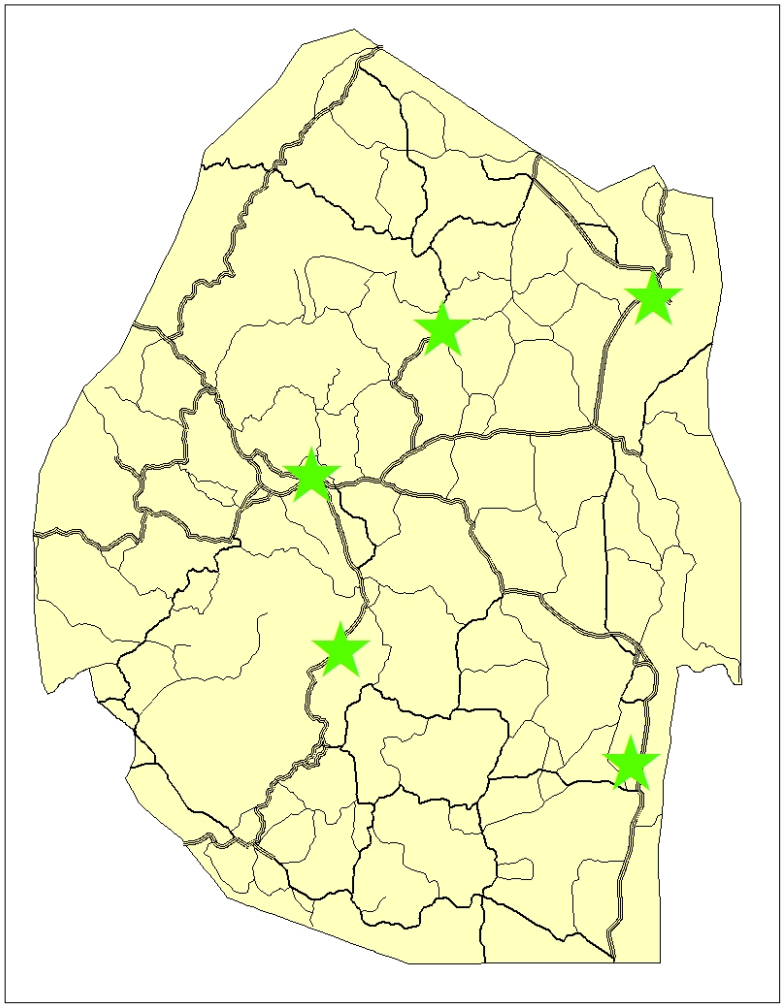


Population

Swaziland: Total Population Distribution 1995

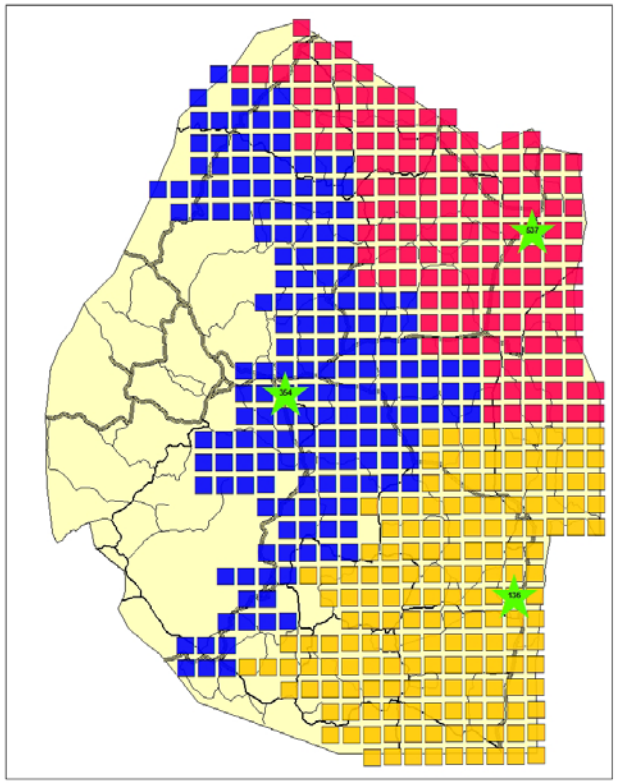


Swaziland: 5 DC Placement

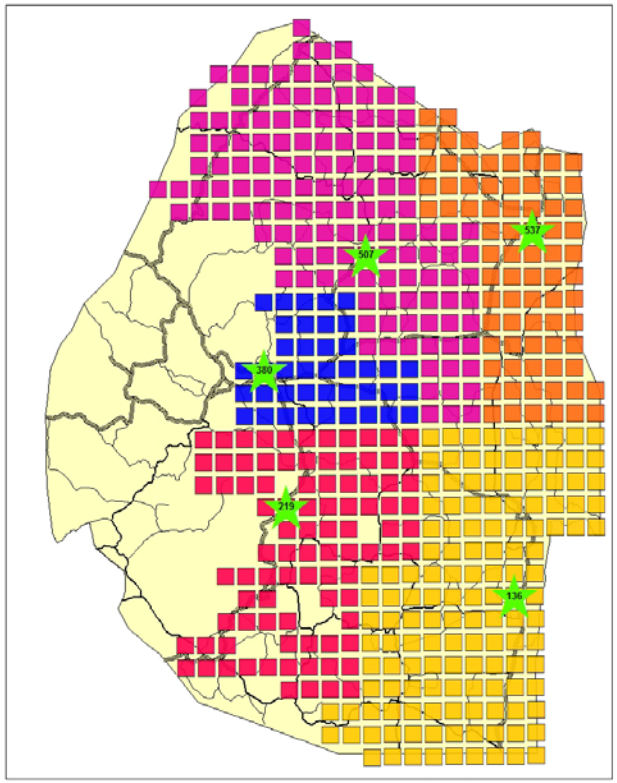


Zone Assignment Heuristic

- Customer zones are serviced by a single DC
  - Straight-line distance: DC to customer zone
  - Road factor of zone considered (paved, unpaved)



Zone Assignment with 3 DCs



Zone Assignment with 5 DCs

IRS Resource Deployment Model

- Objective: Maximize the number of people protected by a prevention method who are at risk of malaria.

- Output: scheduled deployment plan
  - What zones to target for spraying
  - When to deploy in each zone
  - How many people in each zone to protect
  - Resources to base at DCs

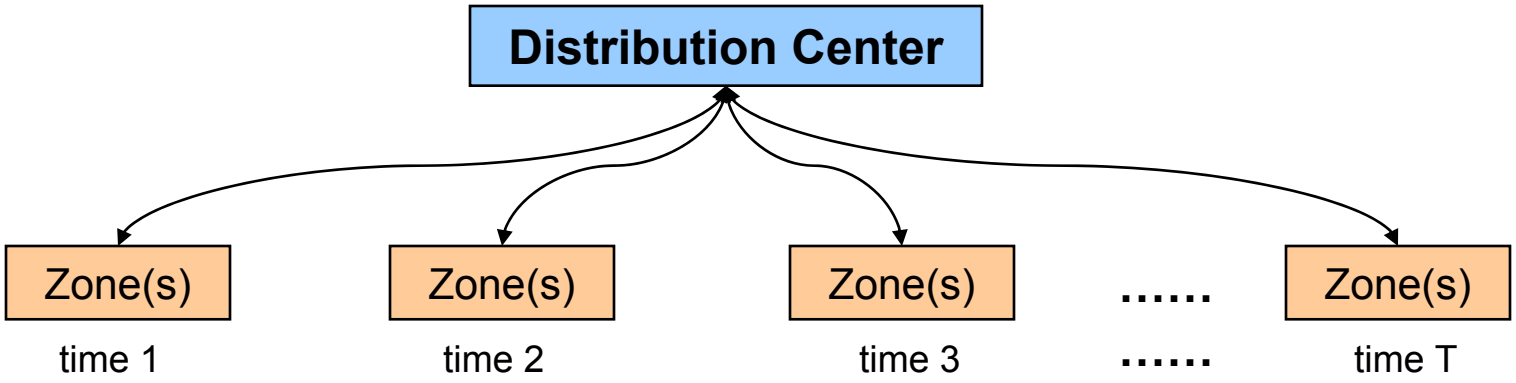
Assumptions

MARA

- Risk and transmission season accurately represented by MARA
- 5x5 km MARA grids aggregated into ~15x15 km zones

Intervention

- IRS with DDT
- Materials ordered once per year, prior to deployment
- 1 spray cycle per year
- Straight line distances adjusted for road conditions of zone



IRS Constraints

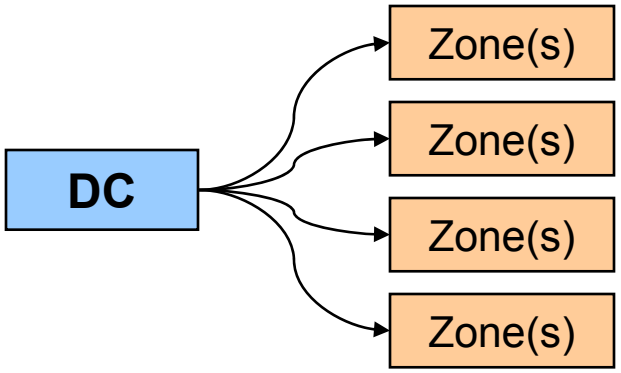
→ Deployment restricted by:

Capacity	Relative Effectiveness	Costs/Budget
•Truck capacity •DC capacity • Amount of resources based at DCs • Zone population	•Duration of DDT effectiveness • Concentration of DDT per m^2 • Coverage rate of spray personnel	• Labor wages • Opening and operating DCs • Vehicle rental and travel costs • Equipment purchase and repair • Cost of DDT

LLIN Resource Deployment Model

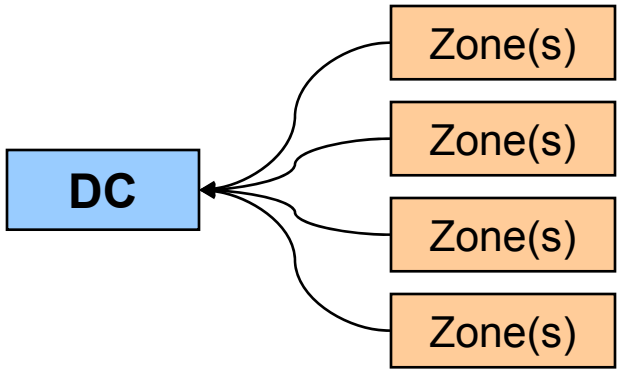
Advertisement of net pickup place and time to zones

time(0) **...** time (DC open)



DCs open for net pickup and instruction on proper use

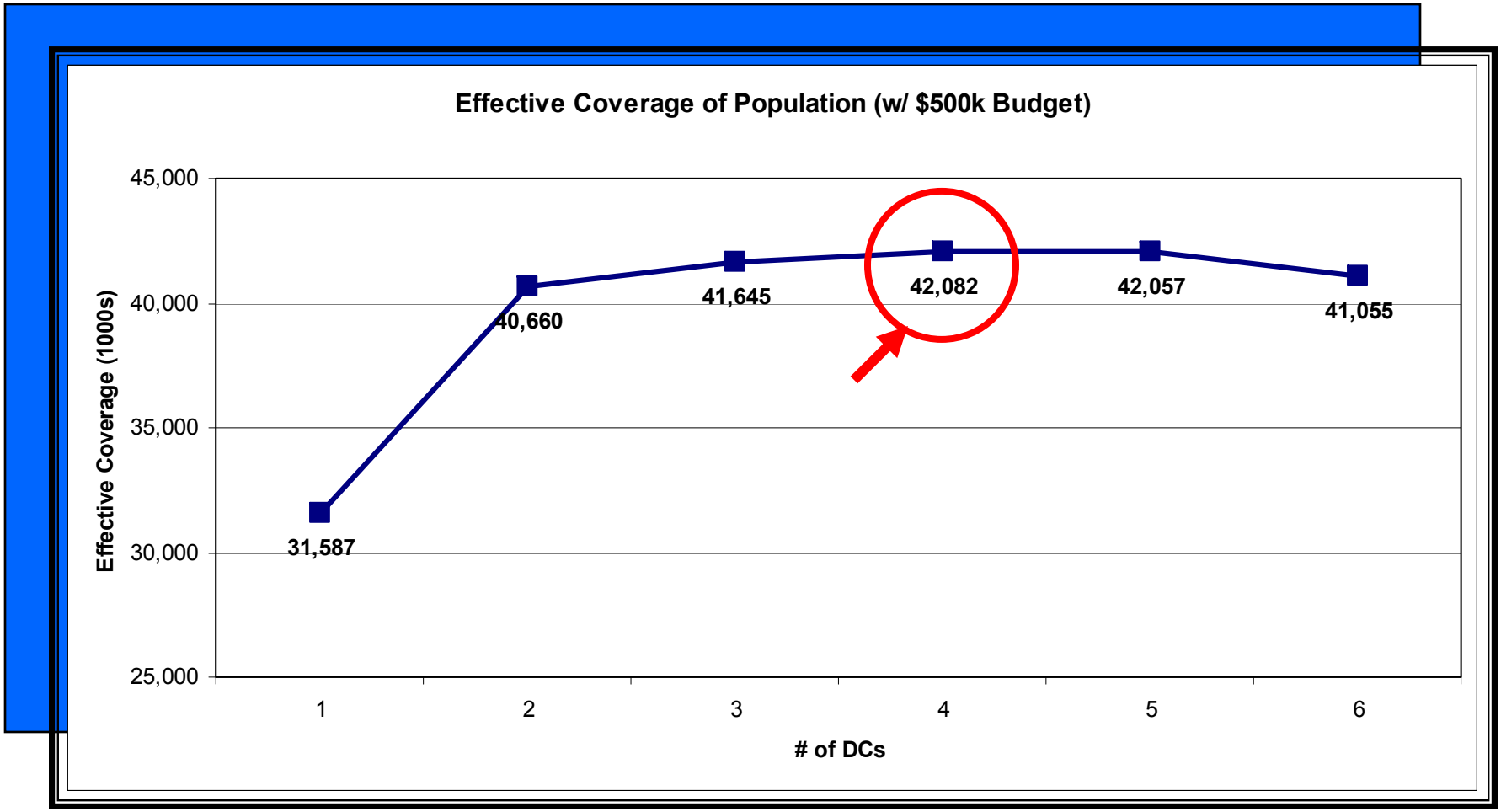
time(DC open) **...** time (DC close)



→ Adapted output

- When to open the DCs
- What zones to target
- Number of public health workers and supervisors at DCs
- Extent of advertising in targeted zones

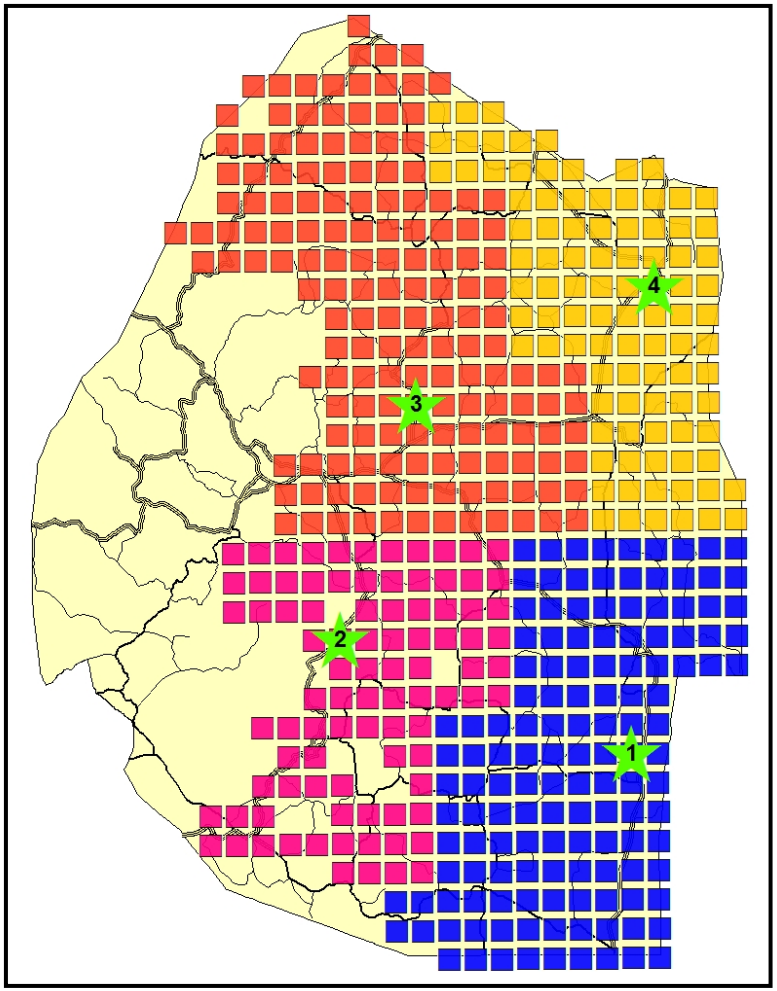
Recommendation



Recommendation

→ Labor based at each DC

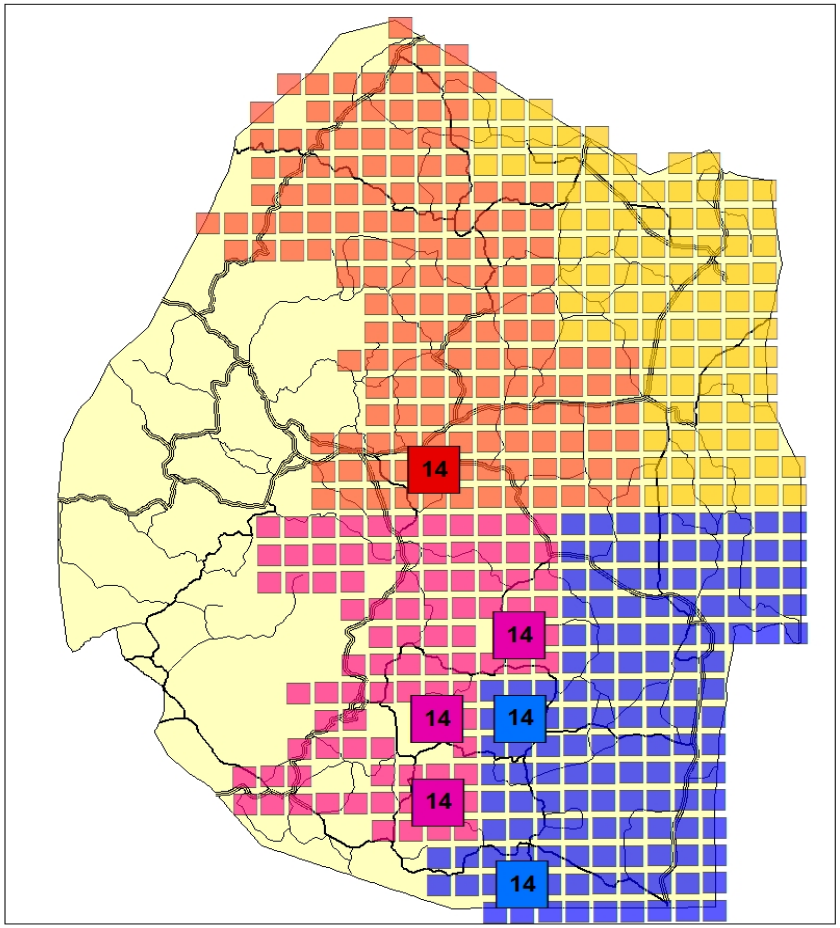
DC	Zone	Labor
1	136	35
2	219	35
3	435	50
4	537	50
5	-	-
6	-	-



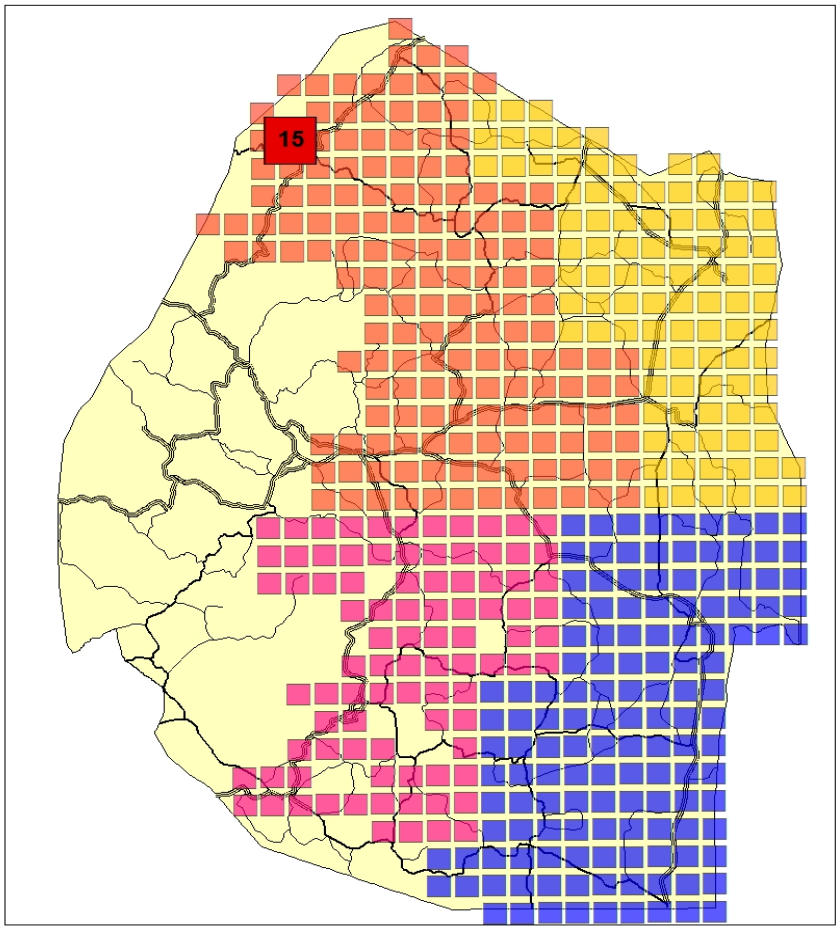
Recommendation

→ Deployment schedule

4DCs: Coverage in Period 14



4DCs: Coverage in Period 15



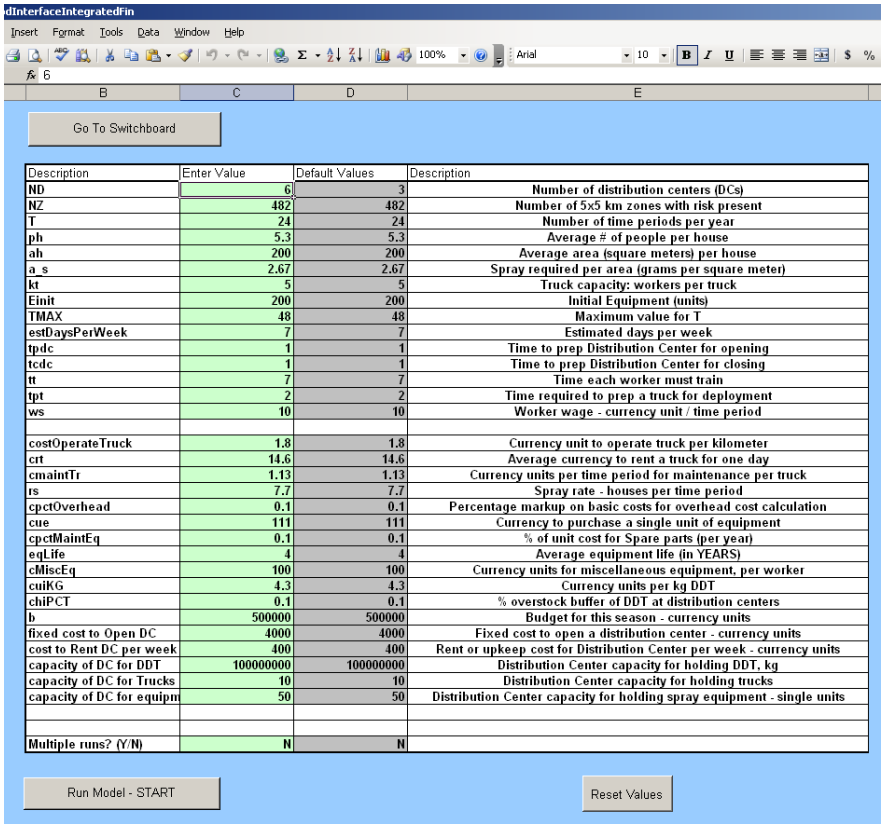
*For full deployment schedule, see animation

Sensitivity Analysis

Parameter: Spray rate per worker (houses/day)				
Factor	**0.1**	**0.9**	**1.1**	**1.9**
Objective Value	8,642,903	40,212,463	42,917,104	46,045,932
Objective Value / Total Cost	17.31	80.42	86.14	92.72
% Δ from base	**-0.795**	**-0.046**	**0.022**	**0.100**
Parameter Value	0.77	6.93	8.47	14.63
% Δ objective / % Δ Parameter	0.88	0.46	0.22	0.11

Model Interface

- Decision-making application using Excel and VBA
  - Linked to Xpress-MP

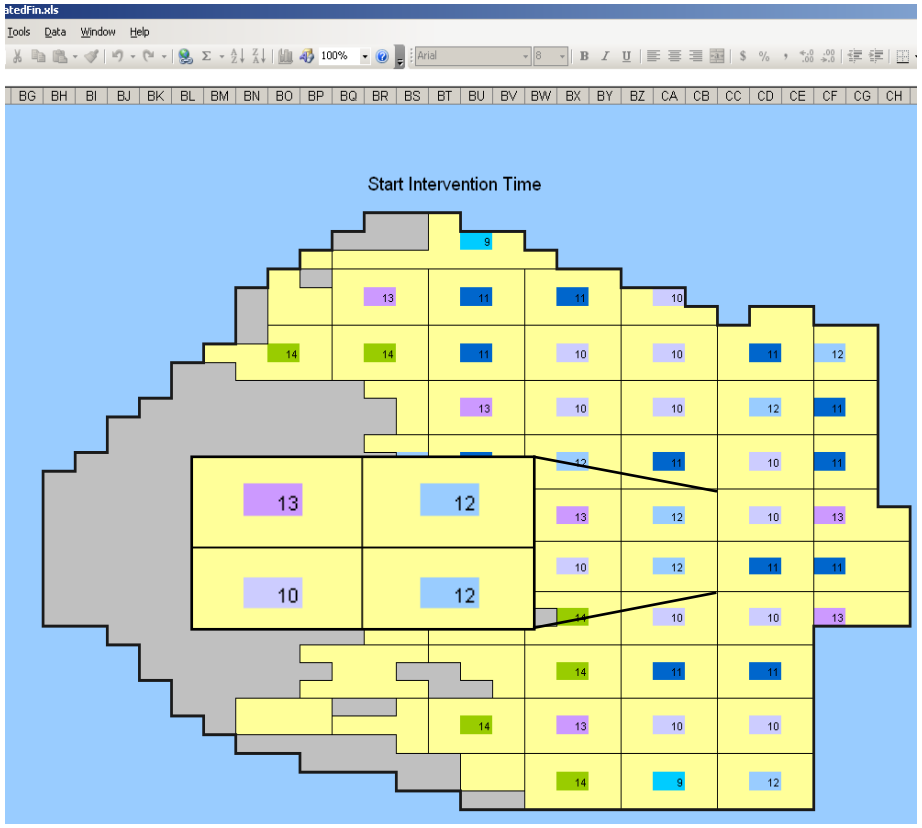


Go To Switchboard

Description	Enter Value	Default Values	Description
ND	6	3	Number of distribution centers (DCs)
NZ	482	482	Number of 5x5 km zones with risk present
T	24	24	Number of time periods per year
ph	5.3	5.3	Average # of people per house
ah	200	200	Average area (square meters) per house
a_s	2.67	2.67	Spray required per area (grams per square meter)
kt	5	5	Truck capacity: workers per truck
Einit	200	200	Initial Equipment (units)
TMAX	48	48	Maximum value for T
estDaysPerWeek	7	7	Estimated days per week
tpdc	1	1	Time to prep Distribution Center for opening
tcdc	1	1	Time to prep Distribution Center for closing
tt	7	7	Time each worker must train
tpt	2	2	Time required to prep a truck for deployment
ws	10	10	Worker wage - currency unit / time period
costOperateTruck	1.8	1.8	Currency unit to operate truck per kilometer
crt	14.6	14.6	Average currency to rent a truck for one day
cmaintTr	1.13	1.13	Currency units per time period for maintenance per truck
rs	7.7	7.7	Spray rate - houses per time period
cpctOverhead	0.1	0.1	Percentage markup on basic costs for overhead cost calculation
cue	111	111	Currency to purchase a single unit of equipment
cpctMaintEq	0.1	0.1	% of unit cost for Spare parts (per year)
eqLife	4	4	Average equipment life (in YEARS)
cMiscEq	100	100	Currency units for miscellaneous equipment, per worker
cuiKG	4.3	4.3	Currency units per kg DDT
chiPCT	0.1	0.1	% overstock buffer of DDT at distribution centers
b	500000	500000	Budget for this season - currency units
fixed cost to Open DC	4000	4000	Fixed cost to open a distribution center - currency units
cost to Rent DC per week	400	400	Rent or upkeep cost for Distribution Center per week - currency units
capacity of DC for DDT	100000000	100000000	Distribution Center capacity for holding DDT, kg
capacity of DC for Trucks	10	10	Distribution Center capacity for holding trucks
capacity of DC for equipm	50	50	Distribution Center capacity for holding spray equipment - single units
Multiple runs? (Y/N)	N	N	

Run Model - START

Reset Values



Deliverables

- Optimization model
  - Description, specification of model
- Decision-making tool
  - Test interface in Excel
  - Output
- Sensitivity analysis
  - Objective response to changes in parameters
- Documentation
  - All assumptions, processes, and methodology

Value

- Use of heuristics to estimate expected current deployment behavior

- 3 heuristic variations, prioritize zones to cover by:
  - Greatest risk first
  - Greatest population first
  - Greatest combined risk and population first

- All variations assume:
  - 1 DC in Mbabane (capital)
  - Equivalent objective, budget, and resource constraints

Value

	$/Person Covered/Year	% Cost Reduction in Model
Model	**$1.32**	**-**
Heuristic 1	**$2.19**	**-39.73%**
Heuristic 2	**$2.52**	**-47.62%**
Heuristic 3	**$2.58**	**-48.84%**
Research Average*	**$2.59**	**-49.03%**

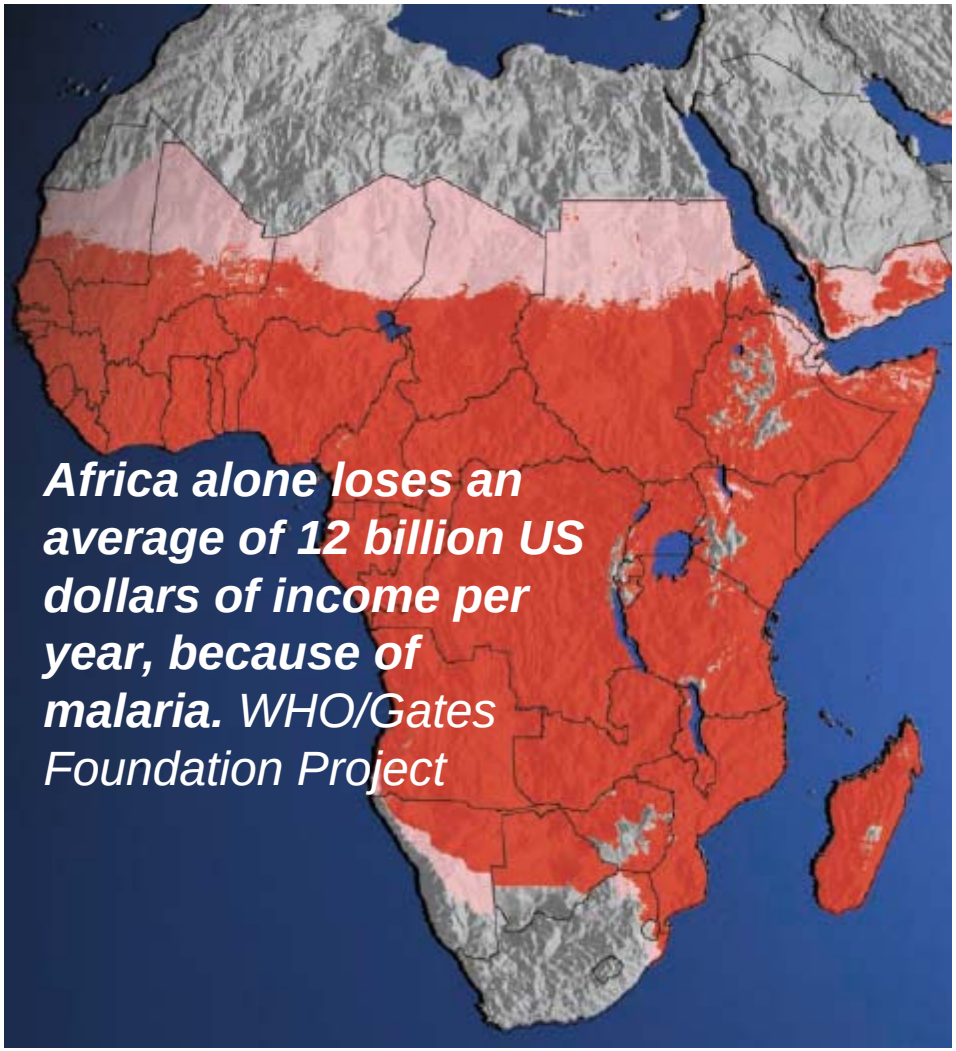
*The American Society of Tropical Medicine and Hygiene, http://www.ajtmh.org/cgi/reprint/77/6_Suppl/138

Value

	Effective Coverage	% Coverage Increase in Model
Model	376,874	-
Heuristic 1	213,087	76.86%
Heuristic 2	187,070	101.46%
Heuristic 3	191,525	96.78%

Value

	# of People (millions)	% of at Risk Population
Total at Risk in Africa	672	-
Current Coverage	193.05	28.73%
Potential Coverage	**378.79**	**56.37%**



Malaria Atlas Project http://www.map.ox.ac.uk

Summary

- Problem Description
- Solution Strategy
- Model
- Recommendations
- Value

Questions?